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ARDH-2 (USS ALAMOGORDO) MOORING INSPECTION REPORT  
COOPER RIVER US NAVAL A. (U) NAVAL FACILITIES  
ENGINEERING COMMAND WASHINGTON DC CHESAPEAKE

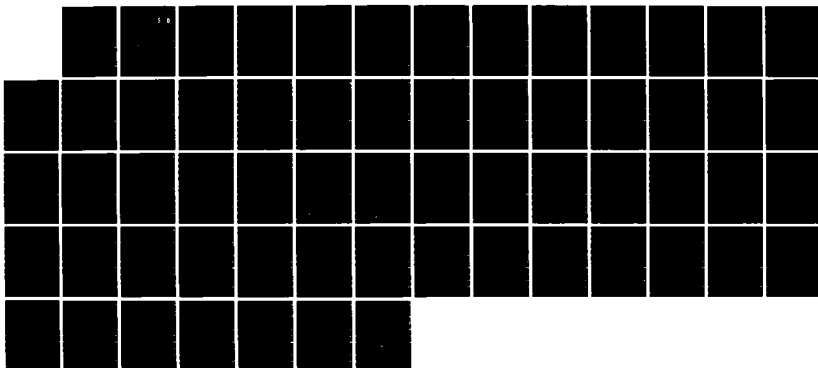
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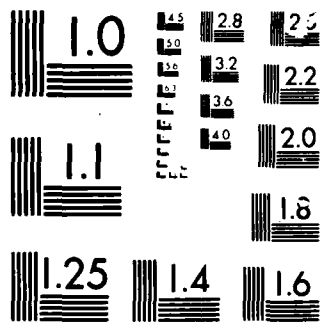
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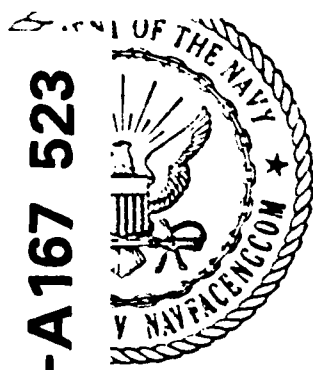


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AD-A167 523

ARDM-2

(USS ALAMOGORDO)

MOORING INSPECTION REPORT

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MAY 02 1986  
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COOPER RIVER

U.S. NAVAL AMMUNITION DEPOT  
CHARLESTON, SOUTH CAROLINA

PREPARED FOR: NAVAL FACILITIES ENGINEERING COMMAND  
ALEXANDRIA, VIRGINIA

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An underwater inspection of the condition of the mooring chains of the ARDM-2, USS Alamogordo, moored in the Cooper River at the U.S. Naval Ammunition Depot, Charleston, S.C., was requested of the Ocean Engineering and Construction Project Office (FPO-1) & the Underwater Construction Team (Con't)

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One (UCT-1) by the Naval Facilities Engineering Command by COMNAVFAC MSG 101944Z August 1978. FPO-1 was tasked to provide the inspection criteria procedures, provide an on-site field engineer, interpret the data and prepare the inspection report. UCT-1 was tasked with performing the underwater inspection. The mooring inspection plan is provided as Appendix 1 and the mooring inspection was completed in November 1978.

ARDM-2  
(USS ALAMOGORDO)  
MOORING INSPECTION REPORT

COOPER RIVER  
U.S. NAVAL AMMUNITION DEPOT  
CHARLESTON, SOUTH CAROLINA

BY  
JACK E. BABER

APPROVED BY: S. C. Ling  
S.C. LING, MANAGER  
ENGINEERING ANALYSIS  
BRANCH

APPROVED BY: C. E. Bodey  
C.E. BODEY, DIRECTOR  
ENGINEERING AND  
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JANUARY 1979

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## BACKGROUND

An underwater inspection of the condition of the mooring chains of the ARDM-2, USS ALAMOGORDO, moored in the Cooper River at the U.S. Naval Ammunition Depot, Charleston, S.C., was requested of the Ocean Engineering and Construction Project Office (FPO-1) and the Underwater Construction Team One (UCT-1) by the Naval Facilities Engineering Command by COMNAVFAC msg 101944Z August 1978. FPO-1 was tasked to provide the inspection criteria and procedures, provide an on-site field engineer, interpret the data and prepare the inspection report. UCT-1 was tasked with performing the underwater inspection. The mooring inspection plan is provided as Appendix 1 and the mooring inspection was completed in November 1978.

## SCOPE

➤ This report describes the inspection procedures, inspection equipment, inspection criteria and summarizes the obtained data. Recommendations concerning the derating of the ARDM-2 mooring chains which did not meet the prescribed criteria are presented. Precautions to be followed in future inspections and potential areas are discussed.

## APPROACH

The basic guidelines for the mooring inspection were provided in the "ARDM-2 Mooring Inspection Plan," Appendix 1. Single and double-link calipers that were machined to 80% and 90% of the standard chain dimensions were used to make the measurements. The diver cleans marine growth and corrosion products from the chain and attempts to slide the 90% calipers or the 80% calipers over the chain section to be measured. This measurement quickly and reliably indicates whether the measured section was greater or less than the nominal measurement. The underwater Ag-AgCl voltmeter was used to obtain an indication of the corroding potential of the chain at/or near the surface or at the lowest position where readings on the digital indicator are discernible. The divers utilized MK-1 diving gear with surface communication equipment and a diesel operated air supply.

## INSPECTION

The inspection procedure was varied slightly from the procedure outlined in Appendix 1, as follows:

- a. One thickness measurement was taken on the chain at the water surface or near the ARDM.
- b. Because of the decrease in visibility along the chain, measurements were taken at 10 foot intervals of water depth as determined by the surface depth indicator of the surface equipment and at the position where the chain entered the bottom mud.
- c. Underwater voltmeter readings were obtained near the ARDM and the lowest position where the underwater voltmeter indicator was visible.
- d. Bearings of the anchors were not obtained because all anchor lines either dropped vertically into the mud of the dredged area of the ARDM-2 mooring site or entered the mud in the dredged area within 50 feet of the ARDM. Changes in current/tide direction and changes in wind direction resulted in a continual slight variation in the angular relationship between the vessel and the chain.

A copy of inspection form for each leg is provided in Appendix 2. In accordance with the downgrading criteria provided in the "Design Manual for Harbor and Coastal Facilities," NAVFAC DM 26, reference (1) and "Mooring Maintenance" NAVFAC MO-124, reference (2) and the guidance provided in Appendix 1 and recommended in reference (3), some of the chains in the ARDM moor were required to be downgraded and re-classified to the load capacity of the next lower standard size chain.

The measured chain diameter on the ARDM-2 mooring legs A, B, C, D, H, and M, (see Figure 1) exceed 90% of the original chain diameter and did not require downgrading in capacity. The measured diameter on the ARDM-2 mooring legs E, F, G, and K exceed 80% of the original chain diameter and should be downgraded in capacity to the next largest standard chain size. The ARDM-2 mooring legs I, J, and L were not inspected because auxiliary barges attached to the ARDM-2 presented a possible safety hazard to the divers. These chains should be tentatively downgraded in capacity to the next largest standard chain size.

The adequate capacity of a mooring chain should be based upon the capability of the weakest link to withstand the maximum design loads anticipated for the moor. The maximum design loads for the ARDM-2 original mooring design are tabulated in Appendix 3. The mooring components that form the weakest portion of each mooring leg are tabulated in Appendix 4. The chain size that corresponds to the smallest size of an anchor joining link or chain joining link is, also, tabulated in Appendix 4. The working capacity of downgraded chains is tabulated in Appendix 5. The present capacity which includes the downrated capacity of each mooring leg is

summarized in Table 1 and it shows that the working capacity of all mooring lines exceed the design load of 120,000 lbs.

If all of the chains were to be downgraded in capacity at a future inspection, the rated capacity of each leg for this downgrading is summarized in Table 2 and it shows that the capacity of the mooring legs still exceeds the design load of 120,000 lbs.

#### SINGLE AND DOUBLE-LINK MEASUREMENTS

The standard double-link measurement criteria is based upon 80% and 90% measurement of double the single wire measurements. These measurements are intended to indicate whether or not the chain links have been degraded by the combined action of wear and corrosion. The predominant mode of degradation of a suspended mooring chain will result from crevice corrosion at the chain link interface. In most forms of crevice corrosion, one boundary or side of the crevice will be degraded more than the other side. As the chain links flex, the corrosion products are removed, a tighter crevice is formed and the process keeps repeating itself. If this degradation cycle only degrades the one link, the capacity of the mooring chain is degraded to a greater extent than initially indicated.

As an extreme example, assume a nominal double-link measurement of a 2 inch chain, i.e. 90% of a double-link measurement is  $0.90 (4.00) = 3.60$  inches, removes 0.40 inches. This amount removed from a single-link results in the removal of 80% of the chain link and under the present criteria the chain must be removed. Since the single link measurement does not measure the diameter of the link at the site of the crevice, the capacity of the chain is likely to be overrated. Additional examinations

of worn chains or mooring components that have been utilized in actual moors should be conducted before the double-link criteria is considered to be a mandatory criteria. Also, mooring components that are situated in the portion of the moor which experiences a continual flexing should be measured in order to verify the validity of single and double-link criteria.

#### COMPARISON OF THE DESIGN LOADS WITH MOORING CAPACITY

In order to evaluate whether or not a mooring chain or any component of a moor can meet the anticipated design requirements, the as-built drawings and the original or revised calculations should be considered before downgrading or replacing a mooring component. In evaluating the mooring for the ARDM-2, the as-built drawings, reference (4), the results of the original design loads, Appendix 3, and a quick check of the chain tension and scope, Appendix 6, were conducted to assure the adequacy of the mooring design. The results are provided in Table 3 and show that the maximum line tension under the design loading is 122,000 lbs. This is approximately 10,000 lbs lower than the working capacity tabulated in Table 1 and approximately 4,500 lbs lower than the maximum working capacity shown in Table 2. Also, under the design loads sufficient chain will remain on the bottom to insure that a  $0^{\circ}$  angle is maintained between the chain and the anchor. According to the as-built drawings, the design holding capacity of the 25,000 lb anchors is 125,000 lbs, therefore, the maximum design load of 122,000 lbs will not exceed the anchor holding capacity.

#### UNDERWATER VOLTMETER READINGS

Underwater potential readings depend on many variables such as resistivity of the water, water flow past the measured point, and relative position of anodic and cathodic areas. Since the river along the ARDM is dynamic and subject to periodic infringement by salt water wedges from the sea and fresh water runoff, the water chemistry is highly variable. The dynamics of active and passive areas on the steel surface and the degree of crevice corrosion, fretting corrosion, general corrosion, pitting, etc., of slowly flexing chain creates a local environment with varying stable potentials at particular instances of time. Further details on the variation of potential readings to the test location and environment are contained in references (5) through (8). Due to the possible variations in the potential reading at the testing point, a conclusive interpretation concerning the significance of the measurements with respect to the condition of the chain cannot be made. The readings will be kept on file for future reference and comparison purposes.

#### ARDM-2, IMPRESSED CURRENT SYSTEM

The impressed current system for the ARDM-2 consists of two-300 amp capacity, SCR controlled constant potential systems. The systems are set to provide a constant negative potential of -0.85 volts and the recorded check voltages show that the potential has remained between 0.84 and 0.89 negative volts. The amperage records show that each of the two systems have been providing a varying amperage output from 10-30 amps to a maximum of 180-250 amps. At the time of the inspection of the anchor chains, the



ship's personnel asked whether or not the system was operating correctly and whether or not there was a logical explanation for the continual output of 150 to 250 amps by both systems. A review of the regular voltage and amperage records along with information concerning the utilization and location of the ARDM-2 at various times revealed the following:

- a. The current demand increased during movement of the ARDM-2 from moorings just off the Charleston Harbor State Port Authority, off the Charleston Naval Shipyard, to the Naval Ammunition Depot on the Cooper River.
- b. Current demand increased when additional barges were securely attached to the ARDM-2 and when the ARDM-2 contained other ships for repair and outfitting.
- c. Current demand increased when there was increased release of freshwater from an upstream dam or during periods of wet weather.

Among the many logical explanations for this varying increase in amperage that is required to maintain the proper control potential of a negative 0.85 volts are the following:

- a. The resistivity of the water would increase during transfer of the ARDM-2 from the Port Authority and the Charleston Harbor to the position on the Cooper River.
- b. The resistivity of the water would increase during additional release of fresh water from upstream dams or runoff from rainwater.
- c. The polarization of localized anodic and cathodic areas was removed by the flow of water past the ARDM-2.
- d. The area requiring protection by the impressed current system increased when additional barges were attached to the ARDM or ships requiring repair or outfitting were loaded into the ARDM.

Although many other factors could contribute to the increased demand in current, the above mechanisms are the most probable causes. Additional information can, also, be obtained in the article "Application of Automatic Potential Controlled Rectifiers in Sea Water Cathodic Protection" by C.R. Ferry in reference (9).

If the capacity of the rectifiers is exceeded, the most practical solution is to attach auxiliary sacrificial zinc anodes to the barges that are attached to the ARDM or attach zinc anodes to the ARDM at locations remote from the impressed current anodes. A convenient method of attaching auxiliary zinc anodes is to rig 150 lb zinc anodes in a flexible cable ladder and firmly secure the ladder to port and starboard sides of the barge or ship. When the barge is removed from the ARDM or the ARDM changes locations, the sacrificial zinc anodes can be stored aboard the ship until needed. These auxiliary anodes should be removed prior to towing or movement of a barge or ship to another location.

The previously cited reference by C.R. Ferry discusses the use of sacrificial anodes in conjunction with an impressed current system and various environmental effects that will change the operational characteristics of the system.

#### SUMMARY OF RESULTS

The following items summarize the results of the inspection of the ARDM-2, USS ALAMOGORDO, moored at the U.S. Naval Ammunition Facility on the Cooper River near Charleston, S.C.:

- a. The chain capacity of legs E, F, G, and K should be downgraded to the next largest chain size on the basis of actual measurements and the chain capacity of legs I, J, and L should be tentatively downgraded.
- b. The mooring capacity of the ARDM-2 in the Cooper River exceeds the design capacity of the moor and does not require removal or replacement of any mooring components at the present time.
- c. The ARDM-2 mooring will exceed the design capacity of the moor even if the lines that did not require downgrading and the downgraded lines are downgraded to the next lower chain size in the future.
- d. The scope of the mooring lines is sufficient to keep the anchors from lifting from bottom even under maximum design loads.
- e. The varying measurements obtained by the underwater voltmeter cannot be used to predict the condition or future condition of this moor.
- f. The anchor capacity of the anchors used in the ARDM-2 moor exceeds the original design loads.

#### RECOMMENDATIONS AND CONCLUSIONS

- a. The presence of an impressed current system or a sacrificial anode system should be known prior to a diver inspection.
- b. The as-built drawings and the original or anticipated design loads for a particular mooring system should be verified prior to inspecting a moor.
- c. The mooring capacity of a moor should be dependent upon the capacity of downgraded components and should not be downgraded just on the basis of a percent change of a particular measurement.
- d. The validity of the double-link chain measurements should be verified because corrosion and wear probably does not uniformly degrade both parts of a crevice/joint uniformly.
- e. The validity of the single-link inspection of suspended mooring chains should be verified because of the joint or fretting surface of a mooring chain cannot usually be inspected in a diver operation.

- (f) The validity of evaluating underwater potential measurements on chain links should be verified because of the great variance in potentials that may be present at a specific location along the moor.
- (g) The subsequent underwater inspection of the ARDM-2 mooring should be programmed at two year intervals. Since underwater inspection is a new effort, this time interval should be reviewed for possible adjustments to reflect information gained from other underwater inspections.

## REFERENCES

1. "Design Manual for Harbor and Coastal Facilities," NAVFAC DM-26, Naval Facilities Engineering Command, Washington, D.C.
2. "Mooring Maintenance," NAVFAC MO-124, Naval Facilities Engineering Command, Washington, D.C.
3. "San Diego Fleet Mooring Inspection," Wadsworth, J.F., Civil Engineering Laboratory Technical Memorandum, M-42-78-12 dated August 1978, Naval Construction Battalion Center, Port Hueneme, California.
4. "Spread Mooring for ARDM, Plan and Details," U.S. Naval Ammunition Depot, Charleston, S.C., Yards and Docks Drawing No. 1046632, Rev. D. dated 7 January 1966, Drawing Code ID No. 80091.
5. "The Electrochemical Basis for Localized Corrosion," by Marcel Pourbaix, pp. 12-33, Localized Corrosion NACE-3, National Association of Corrosion Engineers, Houston, Texas.
6. "Crevice Corrosion of Metals," by France, W.D., Jr., pp. 164-200, Localized Corrosion - Cause of Metal Failure, STP-516, American Society for Testing and Materials, Philadelphia, PA.
7. "What Does 'Potential' Mean?" by Palmer, J.D., pp. 203-211, 17th Annual Appalachian Underground Corrosion Short Course, Engineering Experiment Station Bulletin 106, West Virginia University, Morgantown, W. VA.

8. "Mass Transport and Potential Distribution in the Geometries of Localized Corrosion," by Newman, John, pp. 45-61, Localized Corrosion NACE-3, National Association of Corrosion Engineers, Houston, Texas.
9. "Application of Automatic Potential Controlled Rectifiers in Sea Water Cathodic Protection," by Ferry, C.R., pp. 119-123, Proceedings of 24th Conference, National Association of Corrosion Engineers, Houston, Texas.

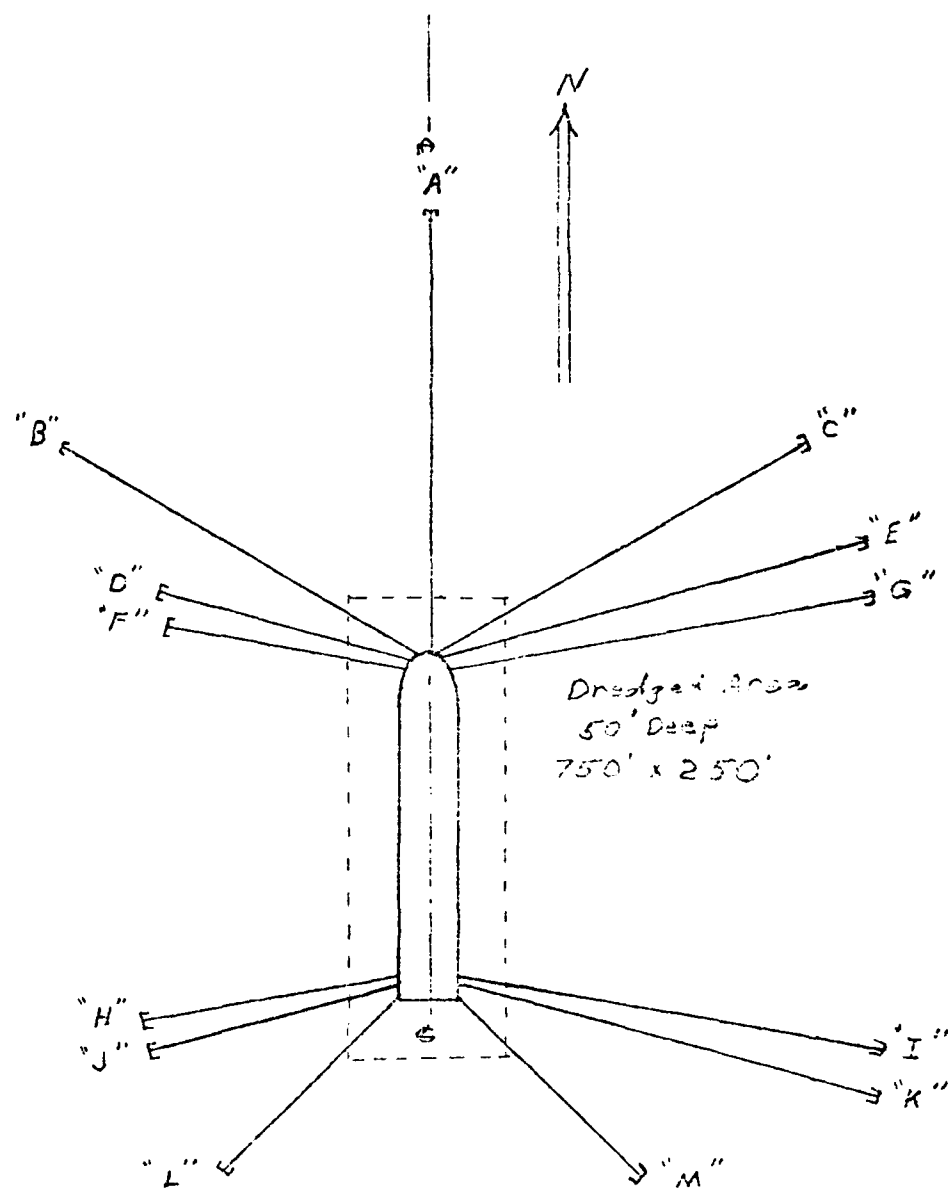


Figure 1. Schematic of Spread Mooring for ARDM-2  
(USS ALAMOGORDO)

TABLE 1.

MOORING LEG WORKING CAPACITY

LEG	WEAKEST LINK	WORKING CAPACITY* (lbs)
A	2-3/16" Stud Link Anchor Chain	131,915
B,C	2-3/16" Stud Link Anchor Chain	131,915
D,H,M	2-3/4" Stud Link Chain	206,130
E,F,G,I,J,K,L	Downgraded 2-3/4" Stud Link Chain to 2-5/8" Chain	188,870

\* Based upon 0.35X Breaking Strength



TABLE 2.

FUTURE DOWNGRADED MOORING LEG WORKING CAPACITY

LEG	WEAKEST LINK	WORKING CAPACITY* (lbs)
A,B,C	2-3/16" Chain Downgraded to 2-1/8" Chain	126,540
D,H,M	2-3/4" Stud Link Chain Downgraded to 2-5/8" Chain	188,870
E,F,G I,J,K,L	2-3/4" Chain Downgraded in Capacity Twice to 2-1/2" Chain	172,270

\*Based upon 0.35X Breaking Strength

TABLE 3.

MAXIMUM TENSION AND % OF CHAIN LIFTED FROM BOTTOM

LEG	MAX. TENSION (kips)	CHAIN LIFTED 2-3/4" Chain	FROM BOTTOM 2-3/16" Chain
A	107.4	0%	65.4%
B	101.3	28.5%	100%
C	101.2	24.8%	100%
D	108.1	81.1%	---
E	108.1	47.7%	---
F	108.6	81.2%	---
G	108.6	48.5%	---
H	116.0	84.0%	---
I	116.0	49.4%	---
J	122.0	86.2%	---
K	122.0	50.7%	---
L	117.0	84.4%	---
M	117.0	84.4%	---
*As-Built configuration, including Rev. D			

APPENDIX 1

ARDM-2  
(USS ALAMOCORDO)  
MOORING INSPECTION PLAN

FPO-1-73(1)  
October 1973

Ocean Engineering and Construction  
Project Office (FPO-1)  
Chesapeake Division  
Naval Facilities Engineering Command  
Bldg. 57, Washington Navy Yard  
Washington, DC 20374

Approved

*C. E. Bodey*  
C. E. BODEY, FPO-1E

*25 Oct 73*

date

*E. F. Spencer*  
E. F. SPENCER, FPO-1C

*25 Oct 73*  
date

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## BACKGROUND

The Ocean Engineering and Construction Project Office (FPO-1) of the Chesapeake Division and Underwater Construction Team (UCT) One have been tasked by NAVFACENCOM to conduct an underwater inspection of an ARDM mooring (figures 1, 2, 3, 4) at Charleston, SC (figure 5). FPO-1 is tasked by COMNAVFAC Msg 101944Z Aug 78 to provide the inspection criteria and procedures, record and interpret the data and write the inspection report. UCT One is tasked with performing the underwater inspection.

## UNDERWATER INSPECTION

### General Procedure

The inspections are intended to be a quick, economical method of establishing the general condition of moorings. The procedures are derived primarily from CEL TM No. M-42-78-12 entitled "San Diego Fleet Mooring Inspection" but are intended to be complete without referring to the reference document. The information derived from these inspections is suitable for maintenance decisions of extent and scheduling of overhauls and certifications of the class of moorings.

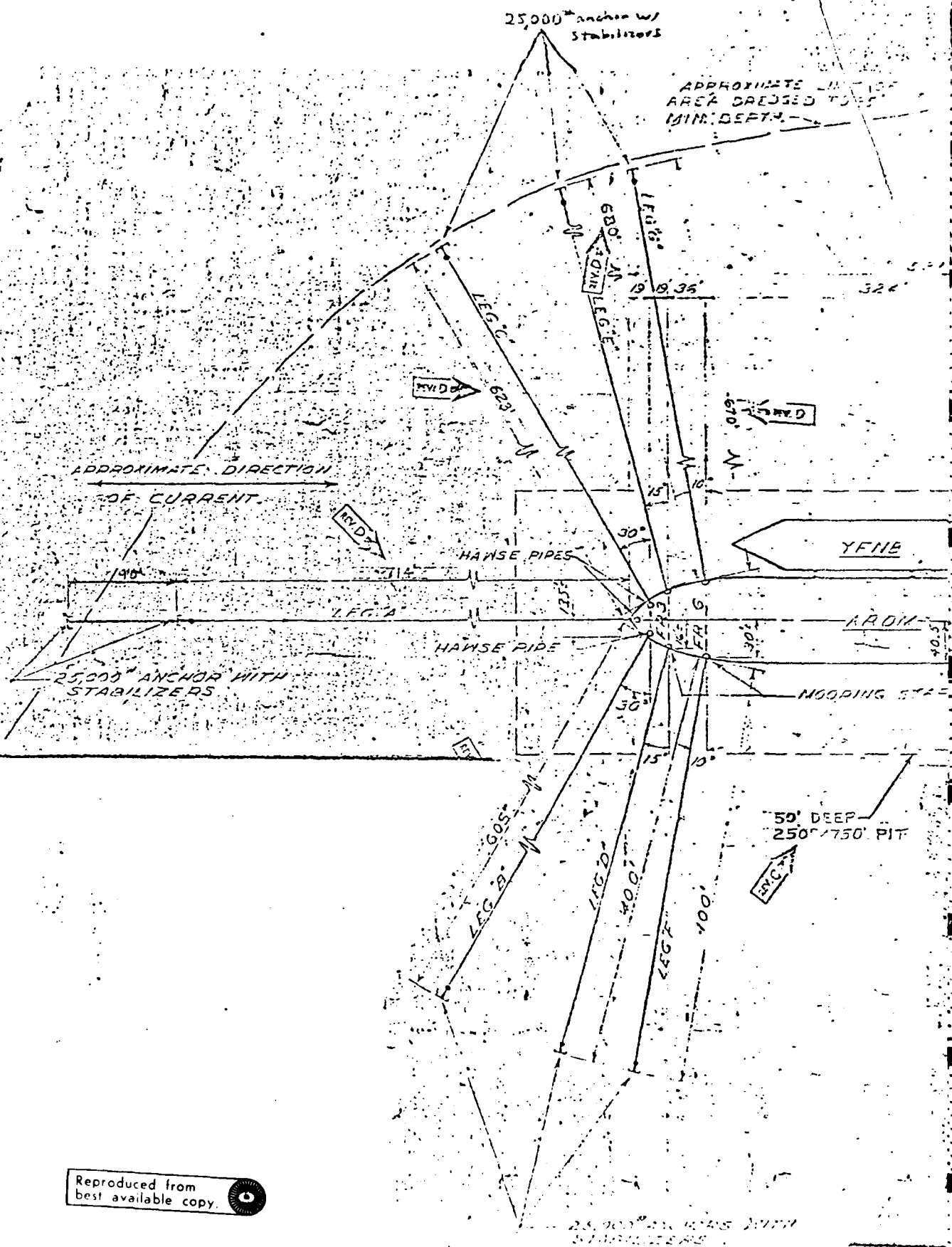
An initial diving check shall be performed to verify the drawings (Y&D Drawing No. 1046632) or parts lists of each mooring (figures 1, 2, 3, 4). Assuming these documents are up to date, the divers can make simple, fast "go, no-go" measurements to establish the mooring condition on the ascent. If the mooring is not as in the drawings, an inventory of what is present must be taken before these measurements can be made.

Each leg of the mooring shall be visually inspected from the surface until it becomes buried in the seafloor or about 30 feet past the wearpoint (where the chain is picked up and set down on the bottom by tides and waves) whichever comes first. Bearing should be taken on this end point to determine the general mooring layout when possible by using a compass. The visual inspection should identify and record any obvious weak points in the chain such as cracked links, highly corroded sections, inoperative shackles and swivels, fouling by extraneous wire rope or chain, and condition of joining links and corrosion protection.

### Measurements

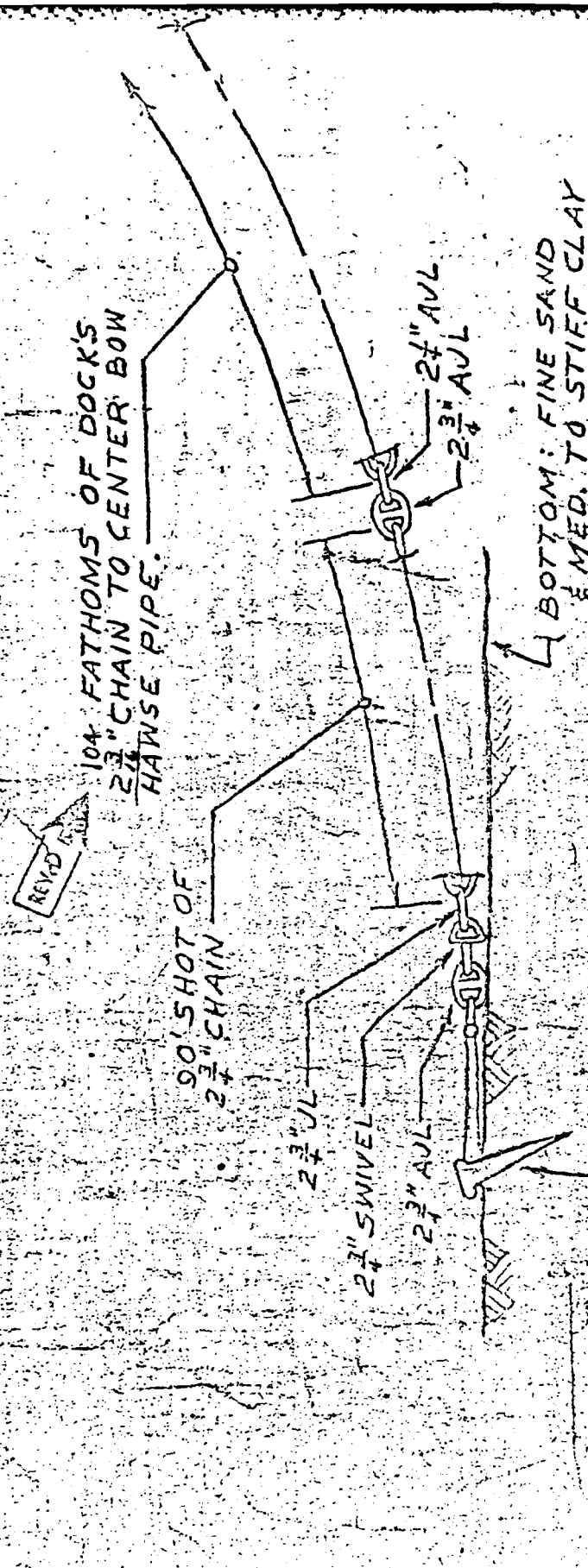
The inspection consists of measuring the chain to determine the amount of corrosion and wear. Chain which is less than 90% of its original diameter should be downgraded in classification; chain which is less than 80% of its





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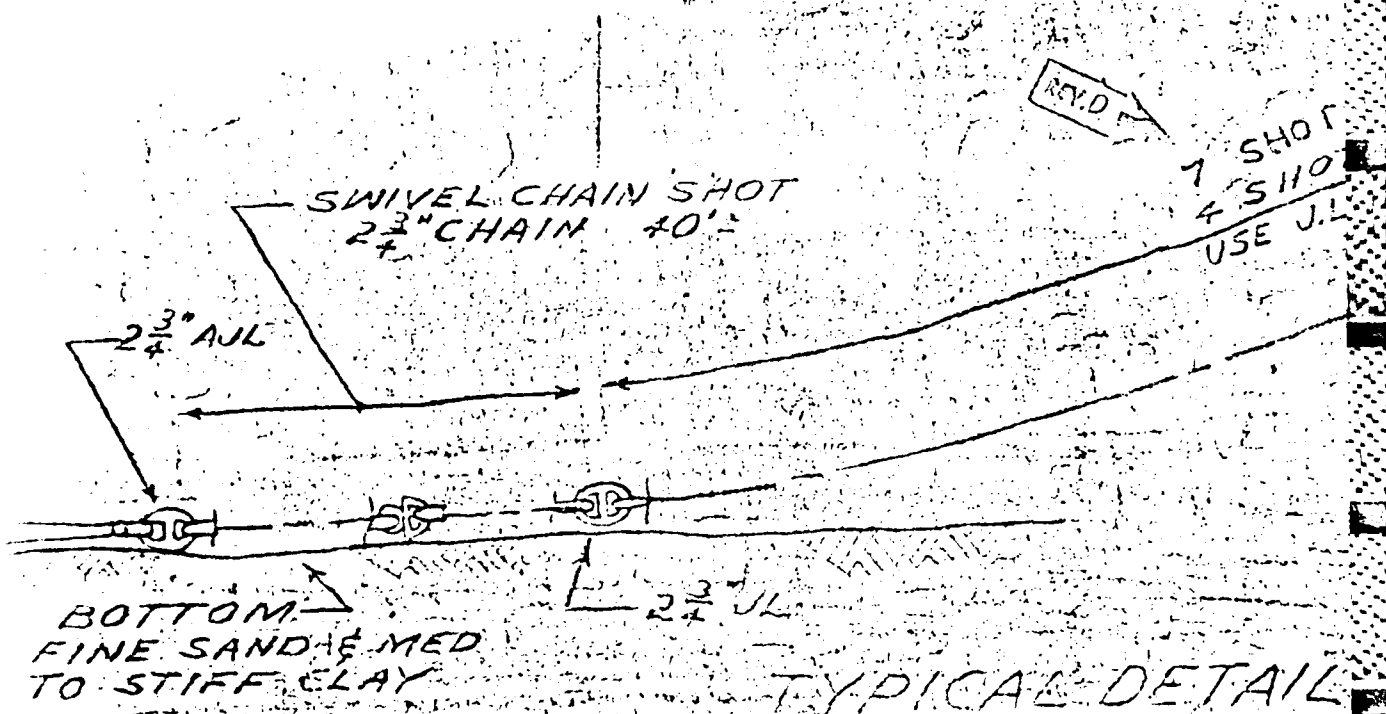
DETAILS - LEG A

NO SCALE

FIGURE 2

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NOTE: MOORING STAPLES ARE GENERALLY SUBMERGED

FIGURE 1

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PULLING EYE  
2 1/2" 3" BALDT  
DETACHABLE ANCHOR  
CONNECTING LINK

WIA IR LINE

7 SHOTS - 2 3/4" CHAIN FOR LEGS E, G, I & K, L & M  
7 SHOTS - 2 3/4" CHAIN FOR LEGS D, F, H, J, L & M  
USE U.L.'S BETWEEN SHOTS

2 3/4" U.L.

2 3/4" U.L.

2 3/4" U.L.

TAILS - LEGS D, E, F, G, H, I, J, K, L, & M

NO SCALE



### Measurements (continued)

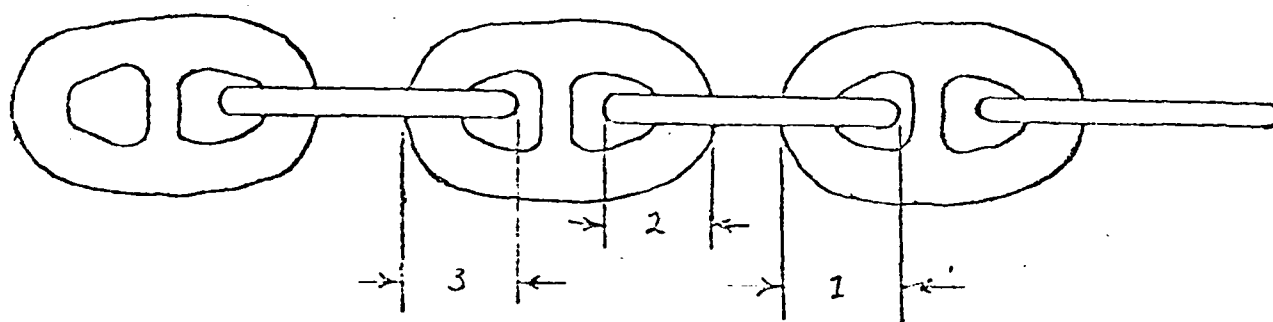
original diameter should be replaced. Single and double link measurements should be performed as in figure 6 at a randomly selected set of links, at areas listed below. Single link measurements on the wire diameter of a single A-link shall be performed to detect corrosion loss; double link measurements shall be taken where the two A-links contact in order to detect wear. Single link measurements should be made on three different diameters on the same approximate cross-section as shown in figure 6. The double link measurements should be made on three adjoining links as shown in figure 6.

The recommended procedure for two divers doing an inspection is as outlined in CEL TM No. M-42-78-12 and repeated below. One diver carries the voltmeter and the inspection form taped to a slate (when MK1 is used results can be recorded on surface instead). Diver 1 removes the growth and corroded materials down to bare metal, makes the caliper measurements and signals the results to diver 2 for recording on an inspection form taped to slate or transmitting using MK1 communications to the FPO-1 representative on the surface. Diver 2 then takes the voltmeter readings and records or transmits them likewise.

### Location of Measurements

A selective measurement approach should be utilized. Areas which are known to corrode or wear rapidly shall be subjected to detailed inspection. These areas include the following:

- a. Chain just below where it is connected to the ARDM
- b. Chain at three equally distributed depths along the riser
- c. Chain at the wear point (where the chain is picked up and set down on the bottom by tides and waves) which can be identified by less fouling or clean chain.
- d. For the bowlines, measurements should be performed midway on the 2 3/16" chain, on both sides of the 2 1/4" anchor joining link (AJL), midway on the 2 3/4" chain, and at the wearpoint. If possible the chain in the hawse pipe should also be inspected. Anchor joining links should be visually inspected. Anchors should also be inspected when visible.



DOUBLE LINK MEASUREMENT



SINGLE LINK MEASUREMENT

FIGURE 6

### Equipment

Calipers should be specially made in advance. Sizes required for the Charleston A&M mooring inspection include 2.48" (90% of 2 3/4"), 2.20" (80% of 2 3/4"), 4.95" (90% double link for 2 3/4" chain), 4.40" (80% double link for 2 3/4" chain), 1.97" (90% of 2 3/16"), 1.75" (80% of 2 3/16"), 3.94" (90% double link for 2 3/16" chain, and 3.50" (80% double link for 3 3/16" chain). All calipers should be accurately machined to  $\pm .005$  inches.

A recommended type of gage is the back to back type (figure 7). Each should be marked so they can be identified by feel underwater. This marking can be accomplished by wrapping tape around each gage to clearly identify the difference between the 80% and 90% calipers.

Cleaning tools such as a chipping hammer and a wire brush are required for cleaning growth and corroded material from the chain prior to taking measurements.

The inspection form (figure 8) is set up for use on each leg. The "other" locations can be used for the extra locations needed to be inspected on the bowlines or other areas that may show up during the visual inspection.

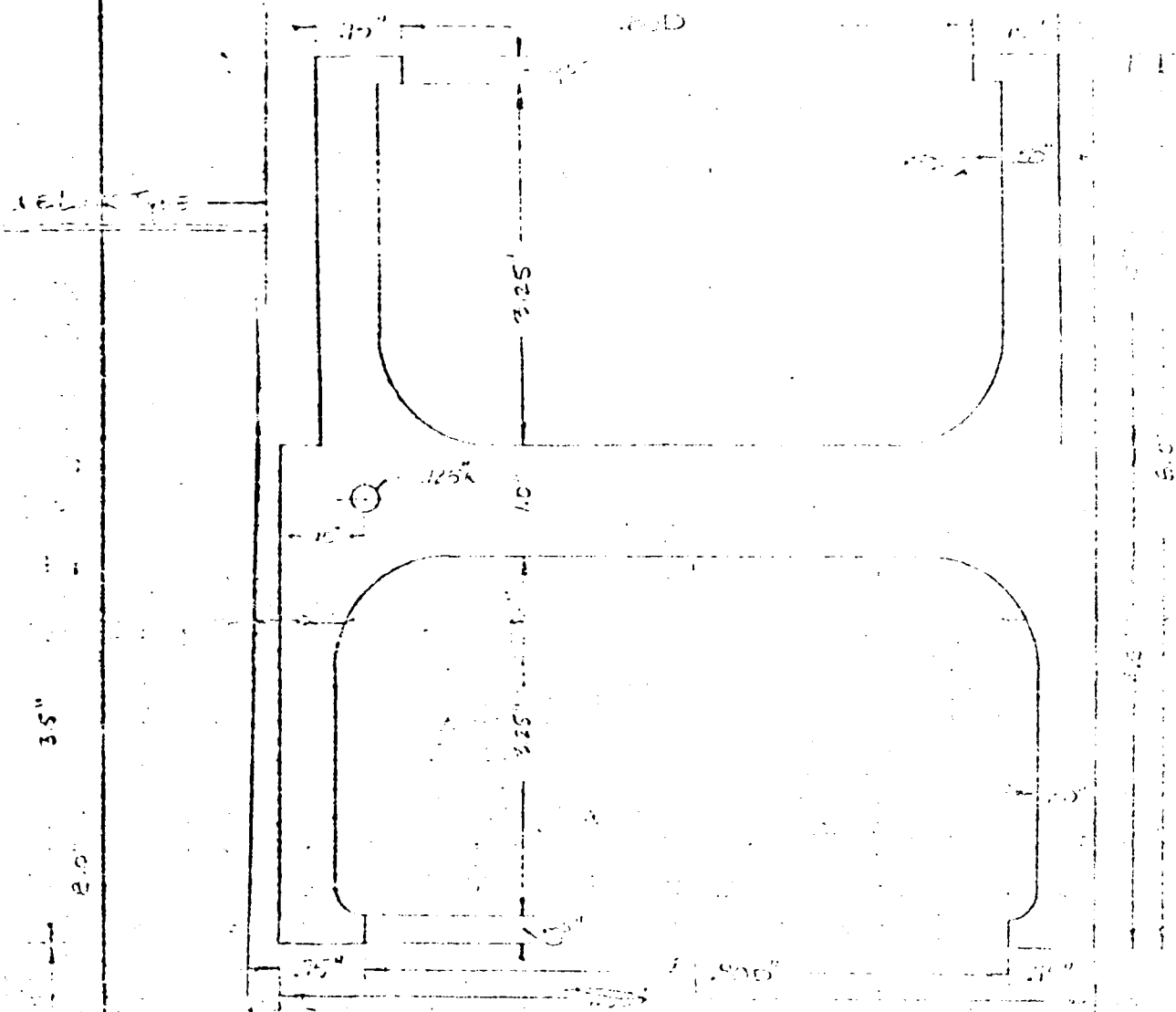
### Reporting

Divers shall provide all inspection data to the on-site FPO-1 engineer who shall write up the inspection completion report and designate the status of each inspected line, i.e., downgrade, replace, or acceptable as is.





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 99. 1/2" THICK  
 100. 1/2" THICK



DOUBLE LINK TYPE

FIGURE 1  
LINK TYPE

APPENDIX 2

INSPECTION REPORTING FORM  
 ARDM-2 MOORING  
 CHARLESTON, S. CAROLINA

Mooring Leg: A

Bearing to Anchor: \_\_\_\_\_

Water depth: 46'

DATE: 11/7/78

DIVERS: Dahl, Chitwood

BOTTOM TYPE: SAND

MUD X

CLAY \_\_\_\_\_

ROCK \_\_\_\_\_

Voltmeter Readings  
11/8/78

11/8/78

LOCATION	WATER DEPTH	NI	CONDITION						U/W VOLT METER READINGS			COMMENTS		
			SINGLE LINK %			DOUBLE LINK %			D	1	2		3	
			90+	80+	80-	90+	80+	80-						
NEAR-ARDM	Surface		X				X							Heavy Growth along chain; Zero visibility at 40ft. At mudline ~ 45', a number of lines are attached to chain
MID-DEPTH	10'		X				X							
MID-DEPTH	20'		X				X							
MID-DEPTH	30'		X				X							
MID-DEPTH	40'		X				X							
OTHER	MUD		X				X							Chain disappears into mud - no joining link picked up
OTHER														

D- Destroyed or broken

NI- Not inspected, inaccessible

INSPECTION REPORTING FORM  
 ARDM-2 MOORING  
 CHARLESTON, S. CAROLINA

Mooring Leg: R Water depth: 47'

Bearing to Anchor: \_\_\_\_\_

DATE: 11/7/78 DIVERS: Dahl, Chitwood BOTTOM TYPE: SAND MUD X CLAY ROCK  
 Voltmeter 11/8/78

LOCATION	WATER DEPTH	MI	CONDITION					U/W VOLT METER READINGS			COMMENTS			
			SINGLE LINK %		DOUBLE LINK %		D	1		2		3		
			90+	80+	80-	90+		80+	80-					
Surface			X				X							Heavy Marine Growth along chain
10'			X				X							
20'			X				X						2'	
30'			X				X							
40'			X											
47'			X											Chain disappears into mud.
MUD														

D- Destroyed or broken.

NI- Not inspected, inaccessible

INSPECTION REPORTING FORM  
ARM-2 MOORING  
CHARLESTON, S. CAROLINA

Mooring Leg: C Bearing to Anchor: Water depth: 45'

DATE: 11/7/78

DIVERS: Dahl / Chitwood  
Voltmeter, 11/8/78

SAND      MUD X CLAY      ROCK     

LOCATION	WATER DEPTH	NI	CONDITION							U/W VOLTMETER READINGS			COMMENTS	
			SINGLE LINK %			DOUBLE LINK %			D	1	2	3		
			90+	80+	80-	90+	80+	80-						
-NEAR-ARM	Surface		X				X				- .469	- .557	- .442	Heavy Marine Growth along chain
-NEB-DEPTH	10'		X				X					3'		
-NEB-DEPTH	20'		X				X							
-NEB-DEPTH	30'		X				X							
-NEB-DEPTH	40'		X				X				- .671	- .673	- .674	
-NEB-DEPTH	45'		X				X					45'		
OTHER	MUD													
OTHER														

D- Destroyed or broken

NI- Not inspected, inaccessible

INSPECTION REPORTING FORM  
ARM-2 MOORING  
CHARLESTON, S. CAROLINA

Mooring Leg: D

Bearing to Anchor: \_\_\_\_\_

Water depth: 49'

DATE: 11/7/78

DIVERS: Venhous

BOTTOM TYPE: \_\_\_\_\_

SAND \_\_\_\_\_

MUD X

CLAY \_\_\_\_\_

ROCK \_\_\_\_\_

LOCATION	WATER DEPTH	HI	CONDITION						U/W VOLT-METER READINGS			COMMENTS	
			SINGLE LINK %			DOUBLE LINK %			D				
			90+	80+	80-	90+	80+	80-	1	2	3		
HEAD ARM	9'		X				X			-.873	-.874	-.869	Heavy Marine Growth along chain 20'- Line wrapped around chain 30'-Current picking up No visibility 40'- Current strong; Growth lighter, line wrapped around chain Chain disappear into mud.
HEAD-DEPTH	21'		X				X				12'		
HEAD-DEPTH	30'		X				X						
HEAD-DEPTH	40'		X				X						
HEAD-DEPTH	49'		X				X			-.590	-.575	-.549	
										-.656	-.645	-.606	
OTHER											48'		
OTHER													

D- Destroyed or broken

NI- Not inspected, inaccessible

INSPECTION REPORTING FORM  
ARM-2 MOORING  
CHARLESTON, S. CAROLINA

Mooring Leg: E

Bearing to Anchor:

Water depth: 46'

DATE: 11/8/78

DIVERS: Beckwith

BOTTOM TYPE: SAND

MUD X CLAY X ROCK

LOCATION	NI	CONDITION							U/W VOLTMETER READINGS			COMMENTS
		SINGLE LINK %		DOUBLE LINK %			D	1	2	3		
		90+	80+	80-	90+	80+					80-	
NEAR ARM	10'		X		X				- .240	- .238	- .239	Little Visibility 20' - Heavy Marine Growth 30' - Visibility decreasing 35' - Start "0" Visibility 40' - "0" Visibility 40' - Heavy Manila line
100-DEPTH	20'	X			X					10'		
100-DEPTH	30'	X				X						
100-DEPTH	40'	X					X					
100-DEPTH	46'		X						- .945	- .930	- .900	
OTHER										28'		Chain disappears into mud
OTHER												

D- Destroyed or broken

NI- Not inspected, inaccessible



INSPECTION REPORTING FORM  
 ARDM-2 MOORING  
 CHARLESTON, S. CAROLINA

Mooring Log: F

Bearing to Anchor:

Water depth: 49'

DATE: 11/7/78 DIVERS: Venhaus, Chitwood BOTTOM TYPE: SAND MUD X CLAY ROCK

Voltmeter Measurements  
 11/8/78

LOCATION	WATER DEPTH	HI	CONDITION						U/W VOLTMETER READINGS			COMMENTS	
			SINGLE LINK %			DOUBLE LINK %			D				
			90+	80+	80-	90+	80+	80-	1	2	3		
	14'		X				X						Manila Line; marine growth along chain
	22'		X					X					Wire Rope Sling
	30'		X					X					Manila Line
	40'		X				X						Lot of Line at 40'
	49'			X									Heavy Marine Growth;
													No Current
													No Growth on Bottom Links
													Chain disappears into mud

D- Destroyed or broken

NI- Not inspected, inaccessible

## INSPECTION REPORTING FORM

ARDI-2 MOORING

CHARLESTON, S. CAROLINA

— 2 : 261 25113001

Bearing to Anchor:

Water depth: 44'

DATE: 11/8/78

**DIVERS:** Beckwith

**BOTTOM TYPE: SAND**

**MUD**

CLAY ROCK

[illegible]

**D- Destroyed or broken**

NI- Not Inspected, Inaccessible

INSPECTION REPORTING FORM  
ARM-2 MOORING  
CHARLESTON, S. CAROLINA

Mooring Log: H \_\_\_\_\_ Water depth: 47'

Bearing to Anchor: \_\_\_\_\_

DATE: 11/9/78 DIVERS: J. Reynolds BOTTOM TYPE: SAND MUD X CLAY X ROCK

Venhaus 10:40 , single link measurement

LOCATION	WATER DEPTH	HI	CONDITION					U/W VOLTMETER READINGS			COMMENTS	
			SINGLE LINK %		DOUBLE LINK %			D	1	2		3
			90+	80+	80-	90+	80+					
HEAD ARM	12'		X				X		-.829	-.820	-.824	Marine growth along chain
<del>ARM-2</del>	20'		X				X			13'		
<del>ARM-2</del>	30'		X				X					
<del>ARM-2</del>	40'		X				X					
<del>ARM-2</del>	47'		X				X					
									-.758	-.757	-.759	Chain disappears into mud
										44'		

D- Destroyed or broken NI- Not inspected, inaccessible

# INSPECTION REPORTING FORM

ARM-2 MOORING

CHARLESTON, S. CAROLINA

Moorings Log: K

Bearing to Anchor: \_\_\_\_\_

Water depth: 45'

DATE: 11/9/78 DIVERS: J. Reynolds BOTTOM TYPE: SAND MUD X CLAY ROCK

double link and voltmeter measurements  
Venhaus 11/10/78- single link measurements

Venhaus 11/10/78- single link measurements

LOCATION	WATER DEPTH	HI	CONDITION						U/W VOLTMETER READINGS			COMMENTS	
			SINGLE LINK %			DOUBLE LINK %			D	1	2		3
			90+	80+	80-	90+	80+	80-					
NEAR ARDM	12'		X							-.372	-.378	-.374	Heavy marine growth along chain 20'- Manila line 35'- wire pendent  Chain disappears into mud
NEAR DEPTH	20'		X								12'		
NEAR DEPTH	30'		X					X					
NEAR DEPTH	40'		X					X					
Mud line - GRAB POINT	45'		X					X			-.649	-.694	-.694
OTHER												41'	
OTHER													

D- Destroyed or broken

NI- Not inspected, inaccessible

Water depth: 44'

**Bearing to Anchor:** \_\_\_\_\_

CONFIDENTIAL

MUD X CLAY ROCK

DIVERS: J. Reynolds, double link and voltmeter measurements  
Venhaus, 11/10/78- single link measurements

DATE: 11/9/78

[illegible]

D- Destroyed or broken

NI- Not inspected, inaccessible

APPENDIX 3

# SUMMARY OF ORIGINAL DESIGN LOADS FOR ARDM-2 SPREAD MOORING

The following design loads were obtained from Mr. Don Potter and are based on the original design of the "ARDM-2 Spread Mooring" U.S. Naval Ammunition Depot, Charleston, S.C., Yards and Docks Drawing No. 1046632:

9.5 Draft, Wind = 70 MPH @  $60^{\circ}$ , Current = 3 Knots @  $0^{\circ}$

A	=	10,400 lbs	
B,C	=	54,500 lbs	
D,E	=	57,800 lbs	Used 60,000 lb design
F,G	=	58,100 lbs	
H,I	=	56,000 lbs	
J,K	=	54,500 lbs	
L,M	=	34,600 lbs	

20 Draft, Wind = 106 MPH @  $60^{\circ}$ , Current = 3 Knots @  $0^{\circ}$

A	=	22,900 lbs
B,C	=	101,000 lbs
D,E	=	105,000 lbs
F,G	=	106,000 lbs
H,I	=	101,200 lbs
J,K	=	98,100 lbs
L,M	=	60,000 lbs

20' Draft, Wind = 106 MPH @ 120<sup>0</sup>, Current = 2 Knots @ 180<sup>0</sup>

B,C = 60,900 lbs

D,E = 74,000 lbs

F,G = 80,000 lbs

H,I = 113,500 lbs

J,K = 119,500 lbs

L,M = 102,000 lbs

#### FINAL DESIGN

20' Draft, Wind = 106 MPH, Current 3-2 Knots

#### Max. Line Loads

A = 105,800 lbs

B,C = 101,000 lbs

D,E = 105,600 lbs

F,G = 106,100 lbs

H,I = 113,500 lbs

J,K = 119,500 lbs

L,M = 114,500 lbs

All lines designed for 120,000 lb loads



APPENDIX 4

AS-BUILT CONFIGURATION ARDM MOOR

MOORING LINE	WEAKEST COMPONENT	Equivalent NEXT COMPONENT=Chain Size	
A	2-3/16" Chain	2-1/4 AJL	2-1/4"
B,C	2-3/16" Chain	2-1/4 AJL	2-1/4"
E thru M	2-3/4" Chain	2-3/4 JL	2-3/4"

APPENDIX 5

# DOWNGRADED STUD LINK CHAIN WORKING CAPACITY

ORIGINAL DIAMETER (INCHES)	DOWNGRADED** DIAMETER (INCHES)	DOWNGRADED BREAKING STRENGTH (POUNDS)	DOWNGRADED WORKING CAPACITY* (POUNDS)
2	1-7/8	284,540	99,590
2-1/8	2	322,000	112,700
2-3/16**	2-1/8	361,530	126,540
2-1/4	2-1/8	361,530	126,540
2-3/8	2-1/4	403,100	141,090
2-1/2	2-3/8	446,660	156,330
2-5/8	2-1/2	492,190	172,270
2-3/4	2-5/8	539,620	188,870
2-7/8	2-3/4	588,930	206,130
3	2-7/8	640,070	224,020
3-1/8	3	693,000	242,550
3-1/4	3-1/8	747,680	261,690

\* From Section 3, Part 7.b, PP. 2(c) Working Load for Used Chain  
 \*\* Downgraded size is next smaller size chain in Table 7-9, DM-26.  
 \*\*\* Size not listed in DM-26, listed as chain size in Baldt Stud  
 Link Chain Dimensions

APPENDIX 6

# MAXIMUM CHAIN TENSION AND SCOPE

Mr. Andrew Del Collo performed the following calculations utilizing the maximum line loads from the final design calculations and the chain size and lengths specified in the as-built drawings for the ARDM-2 Moor. The following table is a summary of the results:

	2-3/4" Chain (kips)	2-3/16" Chain (kips)	Chain Lifted Off Bottom
A	105.8	107.4	0' of 2-3/4", 408' of 2-3/16"
B	101.3	102.7	101' of 2-3/4", 250' of 2-3/16"
C	101.2	102.6	88' of 2-3/4", 268' of 2-3/16"
D	108.1	----	324.2' of 2-3/4" Chain
E	108.1	----	324.2'   "   "
F	108.6	----	324.9'   "   "
G	108.6	----	324.9'   "   "
H	116.0	----	336.0'   "   "
I	116.0	----	336.0'   "   "
J	122.0	----	344.6'   "   "
K	122.0	----	344.6'   "   "
L	117.0	----	337.4'   "   "
M	117.0	----	337.4'   "   "

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